

*EXTINCTION OF RESPONDING MAINTAINED
BY TIMEOUT FROM AVOIDANCE*

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The resistance to extinction of lever pressing maintained by timeout from avoidance was examined. Rats were trained under a concurrent schedule in which responses on one lever postponed shock on a free-operant avoidance (Sidman) schedule (response-shock interval = 30 s) and responses on another lever produced 2 min of signaled timeout from avoidance on a variable-ratio 15 schedule. Following extended training (106 to 363 2-hr sessions), two experiments were conducted. In Experiment 1 two different methods of extinction were compared. In one session, all shocks were omitted, and there was some weakening of avoidance but little change in timeout responding. In another session, responding on the timeout lever was ineffective, and under these conditions timeout responding showed rapid extinction. The within-session patterns produced by extinction manipulations were different than the effects of drugs such as morphine, which also reduces timeout responding. In Experiment 2 shock was omitted for many consecutive sessions. Response rates on the avoidance lever declined relatively rapidly, with noticeable reductions within 5 to 10 sessions. Extinction of the timeout lever response was much slower than extinction of avoidance in all 4 rats, and 2 rats continued responding at baseline levels for more than 20 extinction sessions. These results show that lever pressing maintained by negative reinforcement can be highly resistant to extinction. The persistence of responding on the timeout lever after avoidance extinction is not readily explained by current theories.

Key words: avoidance, extinction, timeout, negative reinforcement, lever press, rats

Avoidance responding can be highly resistant to extinction in certain situations; this observation has been used to help explain clinical phenomena such as phobia and obsessive-compulsive disorder (Levis, 1991; Stampfl, 1987). However, the situations in which great resistance to extinction of avoidance has been noted have usually involved discrete-trial procedures with running or jumping as the response (see Solomon & Wynne, 1954). Lever-press shock-postponement schedules such as Sidman's (1953) procedure generally result in behavior that declines fairly rapidly when shock is removed (e.g., Shnidman, 1968). Such outcomes have been interpreted as supporting theories that lever-press avoidance in the rat has a special

"biologically contraprepared" status that makes it difficult to learn and readily extinguished (Bolles, 1970; Fanselow, 1997; Seligman, 1970). However, analysis of variables influencing extinction of lever-press avoidance has been limited, and it is possible that factors other than the evolutionary status of the response determine the course of extinction (see Heline, 1977).

For example, response rates are generally low under Sidman avoidance schedules unless the response-shock (RS) interval is short, and in such cases contact with shock may complicate interpretation (Baron, 1991; Heline, 1977). Because baseline response rates may exert a major influence on measurement of extinction (Nevin, 1988), comparisons of extinction after positive and negative reinforcement are problematic. It would be of interest to evaluate the extinction of lever pressing maintained at higher baseline rates by negative reinforcement. Recent studies in our laboratory have shown that relatively high baseline response rates can be generated by concurrent schedules in which pressing one lever produces shock postponement under a Sidman schedule and pressing the other lever produces brief periods of timeout avoidance under a variable-ratio

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(VR) schedule (Galizio & Allen, 1991; Galizio & Liborio, 1995). A study of extinction of behavior maintained by timeout from avoidance under these procedures thus allows potential determination of the role of baseline rate and schedule.

An additional feature of interest concerns the comparison between the extinction of behavior maintained by negative and positive reinforcement contingencies. Although extinction of avoidance is most commonly studied by omitting shock, such procedures are not equivalent to those typically used to study extinction of food-reinforced behavior (Baron, 1991; Hineline, 1977). Omission of food as an extinction procedure allows the study of the removal of reinforcement without a change in the establishing operations or motivation (i.e., food deprivation). In contrast, omission of shock in negative reinforcement procedures may be viewed as altering both the motivation to respond as well as the reinforcement for responding. The timeout-from-avoidance procedure provides an interesting alternative because extinction can be arranged under conditions much like those used to produce extinction of behavior maintained by positive reinforcement. That is, the contingency between responses and timeout can be broken while the avoidance schedule (the event that serves as the basis for the reinforcing properties of timeout) remains in effect. Because the avoidance contingency can remain in effect, extinction of timeout from avoidance does not result in unavoidable shock, as would be the case with more traditional escape procedures.

Few studies have examined extinction of behavior maintained by timeout from avoidance. In an early study, Verhave (1962) trained rats on concurrent schedules of Sidman avoidance and fixed-ratio timeout. Extinction was studied in 1 rat by withholding programmed shock and a gradual reduction of responding on both the avoidance and the timeout lever across four experimental sessions was observed. Verhave also studied extinction arranged by nonreinforcement of responding on the timeout lever and reported more rapid declines in responding that resulted in complete extinction within a single session. More recently, Courtney and Perone (1992) trained rats to respond under multiple schedules of variable-cycle avoidance, and

then trained a second response that produced signaled timeout from the avoidance schedules. Extinction was arranged by withholding reinforcement for responses originally maintained by timeout, and resistance to extinction was greater for timeout responding than escaped schedules associated with higher densities of programmed shock. Unlike Verhave's findings, Courtney and Perone found that timeout responding persisted across several sessions of extinction in most of the conditions studied, but extinction arranged by omission of shock was not studied.

The main purpose of Experiment 1 of the present studies was to conduct a direct comparison of two kinds of extinction arrangements. Rats with histories of extensive training on VR timeout-from-avoidance schedules were exposed to extinction conditions that were arranged in some sessions by turning off the shock and in other sessions by withholding reinforcement for responding on the timeout lever while keeping the avoidance contingency in effect.

The timeout-from-avoidance procedure has also served as a baseline in the study of the behavioral effects of a number of psychoactive drugs. In previous studies with the timeout procedure, morphine and related opiate agonists decreased responding maintained by timeout while having no effect on or increasing avoidance (Galizio & Allen, 1991; Galizio, Ordroneau, & Robinson, 1994; Galizio & Perone, 1987). This suggests that morphine in some way reduced the efficacy of timeout reinforcement. Thus, an additional purpose of the present study was to compare within-session effects of extinction with those of the opiate agonist morphine reported previously. Experiment 1 analyzed the extent to which response decrements produced by morphine resembled those produced by both extinction arrangements. In order to permit more direct comparisons with the drug studies, extinction conditions were conducted using probe procedures patterned after those used in the drug experiments in which each extinction session was preceded and followed by one or more baseline sessions with the full contingencies in effect. In Experiment 2, a reversal design was used in which extinction conditions were in effect until a criterion was reached and were followed by a return to baseline.

EXPERIMENT 1

METHOD

Subjects

Four Holtzman mycoplasma-free male rats were individually housed with ad lib access to food and water. They were experimentally naive at the onset of training, which began when the rats were between 80 and 120 days old.

Apparatus

Training took place in Gerbrands G7400 operant chambers approximately 20 cm long, 26 cm wide, and 28 cm high, enclosed in sound-attenuating, ventilated chests. The chambers were equipped with two retractable levers centered 12 cm apart on the stainless steel front wall, 7.5 cm above the floor. The levers required a force of approximately 0.3 N to operate. A 28-V houselight located at the top of the chamber provided illumination. White noise (78 dB) was provided through a speaker located behind the front wall. The floor was constructed of stainless steel rods (0.2 cm diameter), spaced 1.3 cm apart, through which shock (1 mA, 0.5 s) was delivered by a constant-current shock generator and scrambler (Lafayette 82400-SS and 58020). Events in the chambers were controlled and recorded by microcomputers interfaced to the chambers.

Procedure

Preliminary training. Rats were first trained to press the right (avoidance) lever to postpone shock on an unsignaled free-operant (Sidman) avoidance schedule on which each response produced a brief (0.5 s) termination of the white noise (response feedback) and postponed the shock for 30 s (RS interval). The shock-shock (SS) interval, when no intervening response occurred, was 5 s. For 3 rats, white noise and chamber illumination accompanied the initiation of the session and were terminated at the end of each 2-hr session, but for 1 rat (C2) houselight termination signaled the session onset. Training was conducted 5 days per week at about the same time for each rat. Training under these conditions continued until the animals avoided 85% of the programmed shocks (based on the RS interval; see Perone & Galizio, 1987) for 10 consecutive sessions.

In order to establish a discrimination between stimuli that signaled periods of avoidance and timeout from avoidance, the next phase of training was a multiple schedule. Ten-minute avoidance components (houselight and white noise on, except for the animal with reversed houselight conditions) alternated with 10-min timeout components (houselight condition reversed and white noise off, avoidance schedule suspended). Training on the multiple schedule continued until virtually no responding occurred during timeout components.

Variable-ratio training. A concurrent schedule was introduced, with Sidman avoidance contingencies remaining in effect on the right lever and timeout from avoidance available on the left lever. Initially each response on the left lever produced a 5-min timeout signaled by the retraction of the left (timeout) lever, offset of the white noise, offset or onset of the houselight, and suspension of the shock. After consistent responding on the timeout lever had developed, the duration of timeout was reduced to 2 min, and the schedule was gradually changed to VR 15 over several sessions. A 0.5-s reversal of the houselight condition served as feedback for timeout-lever responses. Training continued under VR 15 until stability criteria were met for response rates on both avoidance and timeout levers. For each response the stability criterion was based on the most recent 10 sessions and required that the difference between the means of the first and last five sessions be within 15% of the 10-session mean before the drug studies were initiated. The terminal schedule for the baseline was thus Sidman avoidance (RS = 30 s, SS = 5 s) programmed on one lever and timeout available on a VR 15 schedule on the other. After reaching stability, each of the 4 rats was studied in several drug experiments prior to the extinction study reported here. A minimum of 10 baseline sessions with no drug administration preceded the onset of the extinction study for each rat.

Extinction procedures. Two types of extinction were studied. First, the extinction of the timeout-lever response (timeout extinction) was arranged by suspending the VR 15 schedule such that no timeouts were delivered. Both levers remained in the apparatus, and the Sidman schedule was unchanged. Re-

sponse feedback was still presented on both levers as in ordinary sessions. Thus, timeout extinction sessions were identical to baseline sessions except that responses on the timeout lever no longer produced timeouts. A second type of extinction procedure was arranged by simply turning off the shock generator (no shock) while all other aspects of the procedure remained as in baseline. Thus, the Sidman shock schedule was suspended for the entire session, but feedback was still presented for responding on either lever, and the stimuli signaling session onset were as in baseline. During no-shock sessions, responding on the timeout lever still produced 2-min periods of stimulus change on a VR 15 basis. Thus, no-shock sessions were identical to baseline sessions except that no shocks were programmed. At least five baseline sessions intervened between timeout extinction and no-shock sessions.

Drug procedures. Data from 3 rats originally presented in another paper (Galizio et al., 1994) are reanalyzed here in order to compare the within-session effects of morphine with those produced by the extinction procedures. The training procedures were identical to those described above, except that once stability criteria were met on the VR 15 baseline, morphine injections were administered 15 min prior to session onset on Tuesdays and Fridays. Details of the procedures and full session data have been presented elsewhere (Galizio et al., 1994); thus, only the within-session analysis of a representative dose (3 mg/kg) is presented here.

RESULTS AND DISCUSSION

Table 1 shows the number of sessions for each animal prior to the beginning of each experiment, and also presents response rates and percentage of shocks avoided for 10 ten baseline sessions that preceded the extinction phase. As in previous studies with VR schedules of timeout from avoidance, stable rates of responding were maintained on both levers. Mean response rates maintained under the VR 15 schedule on the timeout lever were always higher than rates maintained under the Sidman schedule on the avoidance lever.

Figure 1 presents a within-session analysis of responding of the 4 subjects of Experiment 1 by dividing the 2-hr session into six 20-min bins. Baseline performances were relatively

Table 1

Baseline performance summaries (mean number of responses per minute on the avoidance and timeout levers and percentage of programmed shocks successfully avoided with standard deviations in parentheses) and total number of sessions prior to the extinction phases.

Rat	Avoidance	Timeout	% avoidance	Total sessions
Experiment 1 only				
S8	4.2 (0.3)	14.2 (1.9)	86 (7.3)	326
W6	6.2 (0.4)	10.1 (2.2)	98 (1.1)	106
Experiments 1 and 2				
C2	7.6 (2.0)	23.7 (4.2)	82 (12.5)	230
D10	4.3 (0.9)	39.7 (7.4)	99 (2.3)	235
Experiment 2 only				
C1	4.8 (0.4)	11.8 (1.8)	99 (0.9)	350
S1	3.9 (0.4)	13.9 (3.7)	94 (4.3)	363

Note. Means are based on the 10 baseline sessions immediately prior to the first extinction session.

stable within the sessions, but there was a small but reliable trend for the highest avoidance rates to occur in the initial 20 min and to decline slightly thereafter. Notably absent were indications of a warm-up effect. In contrast, most rats showed increases across the session in timeout response rates, but this effect was less consistent (note Rat W6), and was large only for Rat C2.

Removing the reinforcement for responding on the timeout lever had immediate effects on responding. Two rats (Rats W6 and S8) showed increases in timeout-lever responding relative to baseline in the first 20-min bin (extinction burst), but the other 2 rats showed declines in responding as early as the first bin (Figure 1). By the second 20-min period, all 4 rats showed pronounced decreases in responding on the timeout lever, while avoidance-lever responding was maintained at baseline levels (or slightly above baseline in the case of Rat S8). Within an hour, all 4 rats showed very low levels of responding on the timeout lever.

In contrast, removing the shock schedule had little effect on timeout response rates. Rat C2 showed some reduction in timeout responding across the session, but the other 3 rats showed virtually no change from baseline (Figure 1). However, avoidance rates did tend to decline across the session in some rats. Although Rats W6 and D10 showed small or no declines, Rats C2 and S8 showed gradually re-

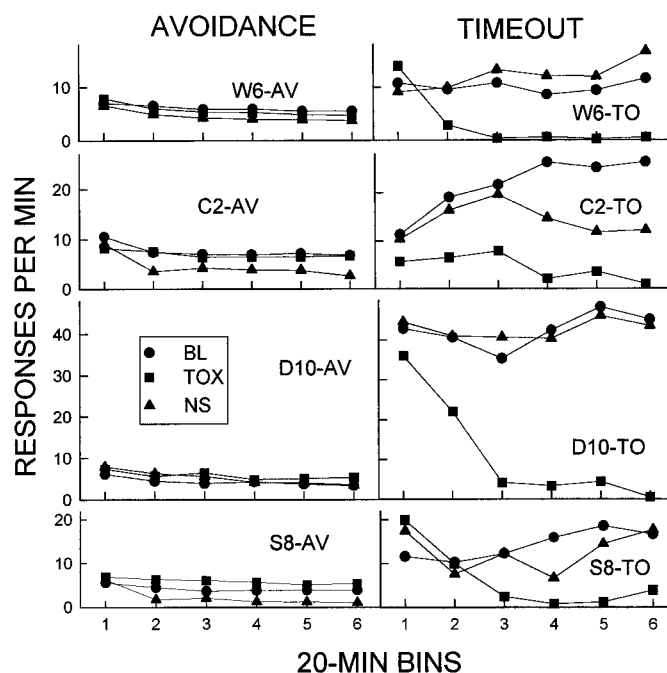


Fig. 1. Effects of withholding reinforcement for timeout responding (timeout extinction [TOX]; squares) are compared with omitting the shock schedule (no shock [NS]; triangles) and with baseline performance (BL; circles). Response rates are plotted as a function of 20-min periods within the session. The left panels show response rates on the avoidance lever, and the right panels show response rates on the timeout lever. Data points represent a single session for the timeout extinction and no-shock conditions and the means of 10 sessions for the baseline conditions.

duced avoidance response rates that, by the end of the session, were approaching zero.

Figure 2 presents a comparable within-session analysis of the effects of 3 mg/kg morphine for 3 rats (reanalyzed from Galizio et al., 1994). Data represent means of two to four probe sessions that were preceded by either saline or 3 mg/kg morphine delivered through intraperitoneal injection. The overall finding of the Galizio et al. study was that 3 mg/kg morphine decreased responding on the timeout lever while having no effect on or increasing avoidance, and Figure 2 illustrates this. For Rat Q18, morphine increased avoidance responding relative to saline throughout the session, and at the same time virtually eliminated responding on the timeout lever from the session onset. Morphine increased avoidance only slightly, if at all, in Rats G31 and C1, but decreased responding on the timeout lever immediately, with some recovery across the session. Thus, the within-session effects of morphine were quite unlike those of extinction conducted under either no-shock or timeout extinction conditions. It

appears that extinction-like mechanisms are insufficient to account for the effects of morphine on the behavior maintained by a timeout from avoidance.

The striking persistence of responding, and particularly of responding on the timeout lever, in the no-shock conditions led to Experiment 2, which investigated the course of extinction associated with omission of shock over many sessions.

EXPERIMENT 2

METHOD

Subjects

Two of the rats from Experiment 1 (Rats C2 and D10) and 2 additional rats with comparable training histories (Rats C1 and S1) served as subjects. Each rat had extensive experience with the concurrent Sidman avoidance and VR 15 timeout-from-avoidance schedules and had been exposed to several drug experiments prior to the extinction study. Numbers of experimental sessions to

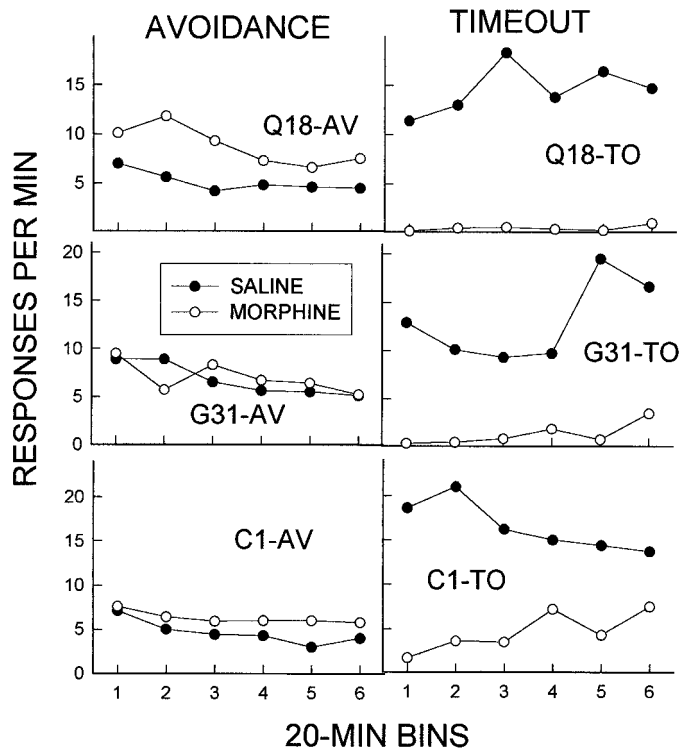


Fig. 2. Effects of a 3 mg/kg dose of morphine (open circles) compared with saline vehicle (filled circles) plotted as a function of 20-min periods within the session. The left panels show response rates on the avoidance lever, and the right panels show response rates on the timeout lever. Data points represent means of two to four determinations, and are reanalyzed from a study presented by Galizio, Ordronneau, and Robinson (1994).

which rats were exposed prior to the onset of the first extinction condition and baseline performance data are presented in Table 1.

Procedure

Apparatus and training procedures were as described in Experiment 1. For Rat S1 houselight offset signaled timeout (as it did for D10), but for Rat C1 houselight onset signaled timeout (as it did for C2). Both Rats C1 and S1 were exposed to at least 10 baseline sessions without drugs before the initial extinction procedure began. For Rats C2 and D10 Experiment 2 began immediately after Experiment 1. The extinction procedures were the same as those described as no shock in Experiment 1: The shock generator was turned off, but all other aspects of the session were identical to those in effect during baseline. Initially, the experimental plan called for the extinction conditions to continue until both timeout-lever and avoidance-lever response rates declined to less than one re-

sponse per minute for three consecutive sessions, followed by a return to baseline for two or more sessions. After 35 2-hr sessions of extinction, only 1 rat (S1) had met this criterion, so a looser criterion of three sessions of relatively stable low rates of responding was adopted. After 100 sessions of extinction, Rat D10 had not met this criterion, but was returned to baseline conditions anyway. For 2 of the rats (Rats C1 and D10), a second extinction phase was arranged after the baseline rates had recovered, and C1 was returned to baseline again following this phase.

RESULTS AND DISCUSSION

Figure 3 shows response rates on both levers for the conditions of Experiment 2. The leftmost panels show performances on the 10 baseline sessions that preceded the extinction condition. Although the baseline rates differed widely, all 4 rats showed stable patterns of responding on both levers, with higher rates generated by the VR 15 timeout sched-

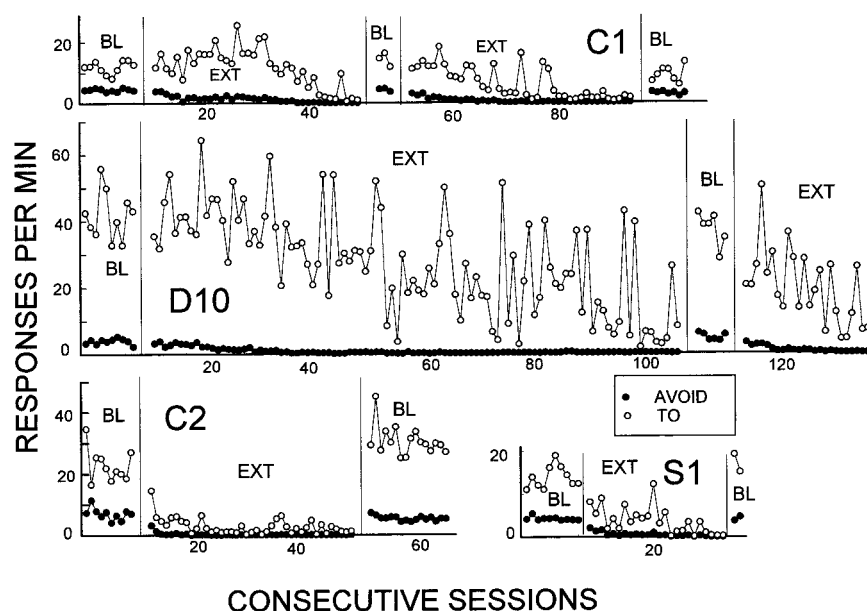


Fig. 3. Response rates on the avoidance and timeout levers for consecutive sessions across the conditions of Experiment 2. Open circles represent responding on the timeout lever, and filled circles represent avoidance response rates.

ule. The next panel shows reactions to the first extinction condition. Reductions in avoidance responding were apparent for Rats C2 and S1 on the initial extinction session, and these 2 rats met the extinction criterion on the avoidance lever within the first few sessions. Several sessions were required before declines in avoidance were noted for Rats C1 and D10, and responding persisted at moderate to low levels for 15 or more sessions. Responding on the timeout lever declined more slowly for all 4 rats. Rats C2 and S1 showed small declines in timeout rate as early as the initial session, but timeout responding persisted many sessions after the extinction criterion had been met for avoidance. Rats C1 and D10 showed little change in timeout rates over the first 20 to 30 sessions. Rat D10 showed considerable variability in responding from session to session, but was still responding at low to moderate rates after 100 extinction sessions. Recovery of baseline performances was rapid in all 4 subjects. Responding on both levers typically approached initial baseline levels on the first session of the return to baseline conditions. Rats C1 and D10 were exposed to a second extinction phase, and Figure 3 shows that although declines in responding occurred

more rapidly during the second extinction, once again avoidance responding declined more quickly than timeout responding did.

Although responding on the timeout lever appeared to show greater resistance to extinction than did avoidance responding (Figure 3), this interpretation is complicated by the higher baseline for timeout rates (cf. Nevin, 1988). Figure 4 represents the data obtained during the initial extinction phase of Experiment 2 as a proportion of the baseline response rate. Responding on the timeout lever still showed greater resistance to change than did avoidance responding, suggesting that the differences in extinction rates cannot simply be explained by baseline rate differences.

GENERAL DISCUSSION

Before considering the extinction data, it is worth noting that there was some evidence of within-session effects found during baseline sessions of all the studies of Experiment 1. There were small, but reliable, tendencies for initial avoidance response rates to be higher than those occurring later in the session (Figure 1). This finding was somewhat surprising, because Sidman avoidance is usually associ-

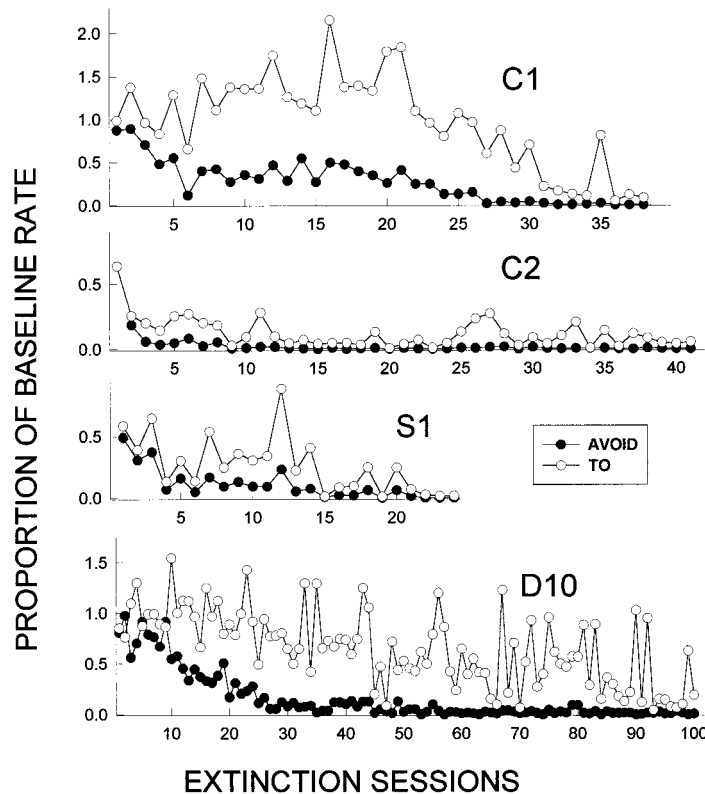


Fig. 4. Response rates as a proportion of baseline rates for consecutive sessions of the initial extinction phase of Experiment 2. Open circles represent responding on the timeout lever, and filled circles represent avoidance response rates. The horizontal axis is on a different scale for Rat D10.

ated with a warm-up effect (Hineline, 1978). The extended training of the present study, as well as the concurrent timeout schedule, may account for the absence of a warm-up effect. In contrast, response rates on the timeout lever tended to increase across the session, or at least were relatively low during the first 20-min bin. Neither avoidance nor timeout response patterns were consistent with inverted U-shaped within-session effects noted by McSweeney and Hinson (1992) with a wide variety of responses maintained by positive reinforcement. Differences in session duration as well as the use of a concurrent schedule in the present study make interpretation of these differences premature.

There were marked differences between the two extinction procedures used in Experiment 1. The effects of discontinuing reinforcement for responding on the timeout lever (the timeout extinction procedure) led to immediate change in timeout lever respond-

ing (Figure 1). Two of the 4 animals (Rats W6 and S8) showed initial increases in responding followed by gradual declines through the rest of the session, whereas the other 2 rats (Rats C2 and D10) showed even more rapid response reductions. These results were quite different from the effects of removing the shock (no-shock conditions), which produced little or no effect on timeout lever responding and decreased avoidance in 2 of the 4 rats. Within-session analysis of the timeout extinction conditions resembled the patterns associated with extinction of behavior maintained by food reinforcement, with extinction bursts (in two cases) and rapid subsequent decline in responding in a single 2-hr session. The contrast between the timeout extinction and no-shock procedures lends substance to the argument that removing shock in an avoidance situation is not analogous to extinction in appetitive settings (e.g., Baron, 1991; Hineline, 1977). Timeout

is a discrete event that, like food, can be withheld following responding during extinction. In addition, omission of timeout as an extinction procedure more closely parallels extinction of food-maintained behavior, because it arranges for the removal of reinforcement without changing the establishing operations, or "motivation," for responding. Thus, it is noteworthy that the timeout extinction procedure resulted in extinction patterns much like those usually associated with positive reinforcement.

One way to interpret the within-session effects of drugs is to compare them with extinction. Because discontinuing shock had little effect on responding, if a drug's action was only analgesic, it would probably have little effect in a single session with this procedure, at least on responding maintained by timeout from avoidance. In contrast, the timeout extinction procedure resulted in within-session declines in responding on the timeout lever. The effects of morphine (Figure 2) were different from those of either extinction procedure. Neither the decreases in responding on the timeout lever nor the increases in avoidance seen in 3 rats changed much during the session. Both effects were apparent immediately and remained throughout the session, so the selective decrease in timeout responding produced by morphine cannot be accounted for in terms of analgesia or an extinction-like mechanism (Galizio & Allen, 1991; Galizio et al., 1994).

Both avoidance and timeout responding showed considerable resistance to extinction in Experiment 2 (Figures 3 and 4). These results contrast with previous findings of rapid extinction of avoidance within a single session (Shnidman, 1968). However, Shnidman studied extinction after just a few sessions of training, whereas the animals studied here had hundreds of hours of training. In each of the 4 rats, responding on the timeout lever showed greater resistance to extinction than avoidance-lever responding. For Rats C1 and D10, timeout responding persisted at high rates for more than 25 sessions, resulting in many thousands of responses during extinction. Thus, contrary to theories emphasizing that biological constraints cause rapid extinction of lever-press avoidance (Bolles, 1970; Seligman, 1970), the present results show that lever-press responding maintained ini-

tially by negative reinforcement can, under certain circumstances, prove highly resistant to extinction.

Perhaps the most significant finding was that avoidance was extinguished more rapidly than timeout responding in all 4 rats of Experiment 2. Even though shock was no longer programmed and avoidance had ceased, stimuli associated with timeout were apparently still capable of maintaining responding. An account of this persistence based solely on stimulus change seems unlikely on the basis of previous research. Perone and Galizio (1987) trained rats to respond on a variable-interval schedule of timeout from avoidance, and then introduced sham timeouts during which the same stimulus changes used in the present study were made (removal of house-light, white noise, and timeout lever retraction) without suspending the avoidance schedule. Under these conditions responding on the timeout lever was rapidly extinguished, but returned to previous levels when baseline conditions with real timeouts were reinstated. These findings, obtained under conditions quite similar to those of the present study, seems to rule out stimulus change per se as a major source of reinforcement. Rather, the reinforcing properties of timeout from avoidance derive from the suspension of the avoidance schedule (Courtney & Perone, 1992; Galizio & Perone, 1987). However, the present results do not support Courtney and Perone's contention that local reductions in response frequency are the basis of the reinforcing properties of timeout. Courtney and Perone presented an analysis showing a close relationship between the reinforcing efficacy of timeout and the response effort associated with the concurrent avoidance schedule. However, in Experiment 2 of the present study, timeout-lever responding persisted after avoidance had been extinguished, suggesting that factors other than response-frequency reduction are important determinants of timeout reinforcement.

Thus, the basis for the greater persistence of timeout responding relative to avoidance that was observed in the present study is of some theoretical interest. The finding seems to be inconsistent with theories of negative reinforcement that emphasize shock-density reduction (Herrnstein & Hineline, 1966) or cognitive theories that emphasize expectation

of shock as underlying avoidance (Seligman & Johnston, 1973) because, from their perspective, once the avoidance response has been extinguished, no further reinforcement should be associated with timeout from avoidance. Similarly, traditional two-factor theory (Mowrer, 1947) would predict that because both avoidance and timeout responses are maintained by termination of stimuli paired with shock, the time course of their extinction would be closely related. One might reconcile with one of the traditional theories by arguing that timeout is a larger magnitude reinforcer and thus produces more resistance to change. Still, a significant problem is posed by the persistence of timeout-lever responding for many sessions in the absence of avoidance. Why should the timeout stimuli retain their reinforcing properties when shock density is zero, and there is insufficient "fear" or "expectation of shock" to motivate avoidance?

Some accounts of negative reinforcement have emphasized the importance of safety signals (Denny, 1971, 1991; Dinsmoor, 1977; Dinsmoor & Sears, 1973; Gray, 1987). These theorists have taken the position that responding in negative reinforcement situations may come under the control of stimuli associated with the absence of shock. The present data might be viewed as consistent with a safety signal account if it is further argued that safety signals develop reinforcing properties that persist even when the initial aversive conditioning situation has lost its power to evoke avoidance responding. Indeed there is evidence from the Pavlovian literature that safety signal functions may persist for extended periods despite wide variations in the initial training conditions, although the removal of the unconditioned stimulus from the situation is eventually sufficient to result in extinction (Fowler, Lysle, & DeVito, 1991; Gray, 1987). However, in the present study both timeout-lever and avoidance-lever responses produced brief feedback stimuli (timeout lever: 0.5-s change in houselight; avoidance lever: 0.5-s white noise termination). These feedback stimuli were well correlated with the absence of shock (shock could be received after a timeout-lever response, so although houselight change was part of the timeout stimulus compound, it was imperfectly correlated with shock omis-

sion). The persistence of responding on the timeout lever may have been controlled by the long duration (2 min) of the timeout stimulus produced when the ratio was completed (see Denny, 1991, for an argument that duration of the safety signal is a critical variable). Another possibility is that the compound nature of the timeout stimulus may have been important in producing the observed persistence (it was always signaled by a change in houselight, white noise, and retraction of the timeout lever; only one brief stimulus change followed each response as feedback). Follow-up research should determine which of the factors is most critical.

Several other unanswered questions make a theoretical analysis of the present data premature. The importance of the different schedules maintaining timeout versus avoidance remains uncertain (cf. Courtney & Perone, 1992). The significance of the extensive training that preceded extinction conditions also remains to be determined. The basis for the much greater resistance to extinction of timeout responding shown by Rats C1 and D10 is unclear.

Despite these questions, the present data suggest that the resistance to extinction of the timeout-lever response may be of importance to animal models of human anxiety disorders. Responding on the timeout lever persisted even after the avoidance response itself had been extinguished. This effect suggests that the timeout-from-avoidance procedure has potential to shed light on the remarkable persistence of anxiety disorders and the apparent dissociation between initial trauma and compulsive behavior in humans (cf. Levis, 1991; Mineka, 1985; Mineka & Zinbarg, 1996; Stampfl, 1987).

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